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Air Force Engineering and Services Laboratory Herbicide Orange Monitoring Program

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ENVIRONICS DIVISION

ENVIRONMENTAL ENGINEERING BRANCH

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	Environmental Monitoring
Herbicide Orange	2,4 Dichlorophenoxyacetic Acid
Agent Orange	2,3,7,8 Tetrachlorodibenzo-p-Dioxin
Dioxin	Ranch Hand
TCDD	Pacer HO
2,4,5 Trichlorophenoxyacetic Acid	Defoliant

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews the Air Force Herbicide orange monitoring Program from 1980 through 1982. Since the ban on the use of herbicides containing 2,4,5 Trichlorophenoxyacetic acid in 1971, the Air Force has conducted a monitoring program at three Herbicide Orange-contaminated sites. This document summarizes studies conducted from 1980 through 1982. Dioxin contaminants found below the soil surface appear to be degrading very slowly, if at all. 2,4,5 Trichlorophenoyacetic acid and 2,4 Dichlorophenoxyacetic acid levels have decreased approximately 70 percent since 1981. Recommendations

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for expansion of the Herbicide Orange Monitoring program are reported.

PREFACE

This report provides interim results of environmental monitoring and evaluation studies of the former Herbicide Orange (HO) stor·ge, loading, and testing sites at Eglin AFB FL, the Naval Construction Battalion Center (NCBC), Gulfport MS, and Johnston Island (JI), Pacific Ocean. These studies were conducted by personnel of the Air Force Engineering and Services Center (AFESC), Engineering and Services Laboratory (ESL) from January 1980 through December 1982 under JON-19002031, PE-62601F.

This report was prepared to present senior Air Force leaders with the latest available data in the continuing environmental monitoring and evaluation studies at these critical sites. Recommendations reflect AFESC interpretation of collected data and current Environmental Protection Agency guidance. The AFESC/RDVW project officers were Maj Ron E. Channell and Capt Terry L. Stoddart.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service. At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(CONCLUDED)

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

A. BACKGROUND

In April 1970, the Secretaries of Agriculture; Health, Education, and Welfare; and the Interior jointly announced the suspension of certain uses of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). This suspension resulted from published studies indicating that 2,4,5-T was a teratogen. Subsequent studies revealed that the teratogenic effects resulted from a toxic contaminant in the 2,4,5-T, identified as 2,3,7, 8-tetrachlorodibenzo-p-dioxin (TCDD).[a] Subsequently, the Department of Defense suspended the use of Herbicide Orange (HO), which contained 2,4,5-T. At the time of the suspension, the Air Force had an inventory of 1.37 million gallons of Herbicide Orange in South Vietnam and 0.85 million gallons at the Naval Construction Battalion Center (NCBC), Gulfport MS. In September 1971, the Department of Defense directed that the HO in South Vietnam be returned to the United States and that the entire 2.22 million gallons be disposed of in an environmentally safe and efficient manner. The 1.37 million gallons were moved to Johnston Island (JI), Pacific Ocean in April 1972. The average concentration of dioxin in the HO was about 2 parts per million with the total amount of TCDD in the entire HO stock estimated at 44.1 pounds.

Herbicide Orange is a reddish-brown to tan liquid, soluble in diesel fuel and organic solvents, but insoluble in water. One gallon of HO theoretically contained 4.21 pounds of the active ingredient 2,4-D and 4.41 pounds of the active ingredient 2,4,5-T. Herbicide Orange was formulated to contain a 50:50 mixture (by weight) of the n-butyl esters of 2,4-D and 2,4,5-T. The percentages of the formulation typically were:

n-butyl ester of 2,4-D	49.49
free acid of 2,4-D	0.13
n-butyl ester of 2,4,5-T	48.75
free acid of 2,4,5-T	1.00
inert ingredients (e.g., butyl alcohol and ester moieties)	0.63

Various disposal techniques for herbicide orange were investigated from 1971 to 1974 (Reference 1). Destructive techniques included soil biodegradation, high-temperature incineration, deep-well injection, burial in underground nuclear test cavities, sludge burial, and microbial reduction. Techniques used to recover a useful product included activated charcoal filtration, return to manufacturers, fractionation, and chlorinolysis.

a = The word "dioxin" in this report refers to 2,3,7,8 - TCDD.

Of these techniques, only high-temperature incineration was sufficiently developed to warrant further investigation. The other methods were rejected because of several considerations, including long lead times for development, inadequate assurance of success, and the lack of industrial interest.

During the summer of 1977 the United States Air Force (USAF) disposed of 2.22 million gallons of HO by high-temperature incineration at sea. This operation, Project PACER HO, was accomplished under very stringent regulation by the U.S. Environmental Protection Agency (EPA) ocean-dumping permits (Reference 2).

The Air Force Plan and the EPA permits for the disposal of the herbicide committed the Air Force to a follow-on storage site reclamation and environmental monitoring program. The major objectives of this program were to:

(1) Determine the magnitude of HO contamination (TCDD) in and around the former HO test and storage sites.

(2) Determine the rate of natural degradation for the phenoxy herbicides (2,4-D and 2,4,5-T), their phenolic degradation products, and TCDD in soils of the storage and test sites.

(3) Monitor for potential movement of residues from the storage and test sites into adjacent water, sediments, and biological organisms.

(4) Recommend managerial techniques for minimizing any impact of the herbicides and Dioxin residues on the ecology and human populations near the storage and test sites.

Immediately following the at-sea incineration in 1977, the USAF Occupational and Environmental Health Laboratory (USAF OEHL) initiated site-monitoring studies of chemical residues in soil, silt, water, and biological organisms associated with the former storage sites where the herbicide had been stored at the NCBC and JI. The results of the NCBC and JI monitoring studies have been published (References 3 and 4). A similar monitoring program has been at Eglin AFB, FL since 1973 for a 92-acre site on Test Area C-52A (References 5 and 6) and since 1975 for a 2-acre area on Hardstand 7 (Reference 7).

Secretary of the Air Force/Deputy for Environment and Safety (SAF/MIQ) requested and received from Air Force/Surgeon General (AF/SG) in June 1980 a proposed research protocol to return HO-contaminated sites to full and beneficial use. Based on this research protocol, SAF/MIQ recommended that AFESC/RD Engineering and Services Laboratory (ESL) be designated as lead laboratory for monitoring and reclamation research. Air Force Deputy Chief of Staff for Engineering/ Logistics (AF/LEE) agreed that the

Environics Division of ESL was eminently qualified to handle the complex integration of environmental chemistry and control technology required to address the problem. It was noted, however, that the ESL is dedicated to a research mission and not routine field assistance tasks. This required that site monitoring be consolidated within the dioxin research program, rather than in routine analyses, which is the mission of the OEHL. Before initiation of the overall research program the ESL routed the research requirement through Air Force Deputy Chief of Staff for Research and Development (AF/RD) and Air Force Systems Command/ Director of Laboratories (AFSC/DL) in the form of a Statement of Operational Need (SON). The validated USAF SON 2-81 directed that (1) a sampling and analysis program be initiated, (2) a small program to look at methods to destroy in situ dioxin be started, but no full-scale effort take place unless further directed by SAF, and (3) progress on assessing long-term breakdown and movement of dioxin be discussed yearly at the Headquarters Air Force Engineering and Services Center, Engineering and Services Laboratory (HQ AFESC/RD) - HQ AFSC/DL 6.2 technical review. Following the 1981 HQ AFESC/RD technical review by HQ AFSC/DL, the AFESC/RD was directed by AFSC/DL to (1) proceed with the HO program as a minimal effort involving site monitoring and assessment of the contaminated sites and (2) provided further direction not to carry out actual cleanup unless directed by Headquarters, USAF.

The Environics Division of the ESL has continued the site monitoring and evaluation program by collecting samples from NCBC, JI, and Eglin AFB on a semiannual basis. This report summarizes the data on samples collected from September 1980 through November 1982.

SECTION II

DESCRIPTION OF AIR FORCE DIOXIN-CONTAMINATED SITES

A. JOHNSTON ISLAND, PACIFIC OCEAN (JI)

Johnston Island, a coral atoll (Figure 1), is located 750 nautical miles southwest of Honolulu in the central Pacific Ocean. The island is 1/2 mile wide and 2 miles long with a mean elevation of 7 feet above sea level.

The island is controlled by Field Command of the Defense Nuclear Agency (FC/DNA). The Army and Coast Guard have tenant units assigned to the island totalling 80 personnel. Base support is provided by a civilian contactor which maintains approximately 200 employees onsite.

Ten acres of Johnston Island served for storage and support operations for 1.27 million gallons of Herbicide Orange returned from the South Vietnam. The operational areas included de-drumming, drum crusher and decontamination facilities.

The island is maintained as a contingency base for high-priority defense operations.

B. NAVAL CONSTRUCTION BATTALION CENTER, GULFPORT, MS (NCBC)

The NCBC is located in Gulfport, MS (Figure 2). The NCBC is located approximately 2 miles from the Gulf of Mexico and occupies a land area of several square miles. The NCBC is approximately 20 feet above sea level. The soil is sand to sandy loam, intermixed with some clay.

Approximately 12 acres at the NCBC served as a storage site for 0.85 million gallons of Herbicide Orange. The "old" storage site was stabilized with portland cement approximately 30 years ago. The stabilized soil provided a hardened storage area for heavy supplies and equipment. Over the years, additional fill material (shell, rock and soil) was added to the storage area, providing a cover of several inches over the cement-stabilized soil.

Approximately 2-4 acres of the 12-acre site are considered contaminated with herbicide orange and its associated dioxin. During 1980, retention basins were constructed on the storage site to prevent the migration of dioxin-contaminated soils off-site. Currently the "old" Herbicide Orange storage site is a restricted area and is not used.

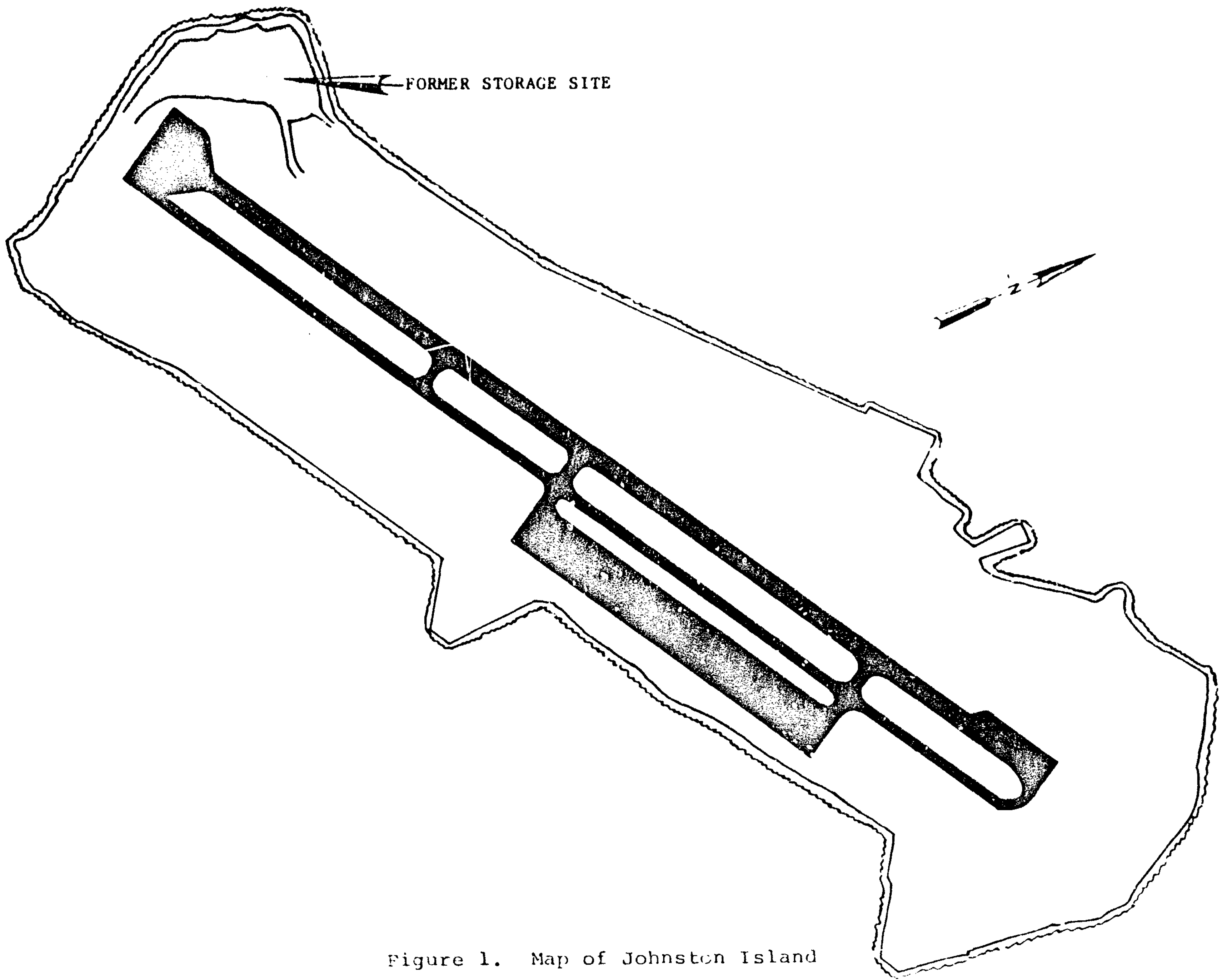

Figure 1. Map of Johnston Island

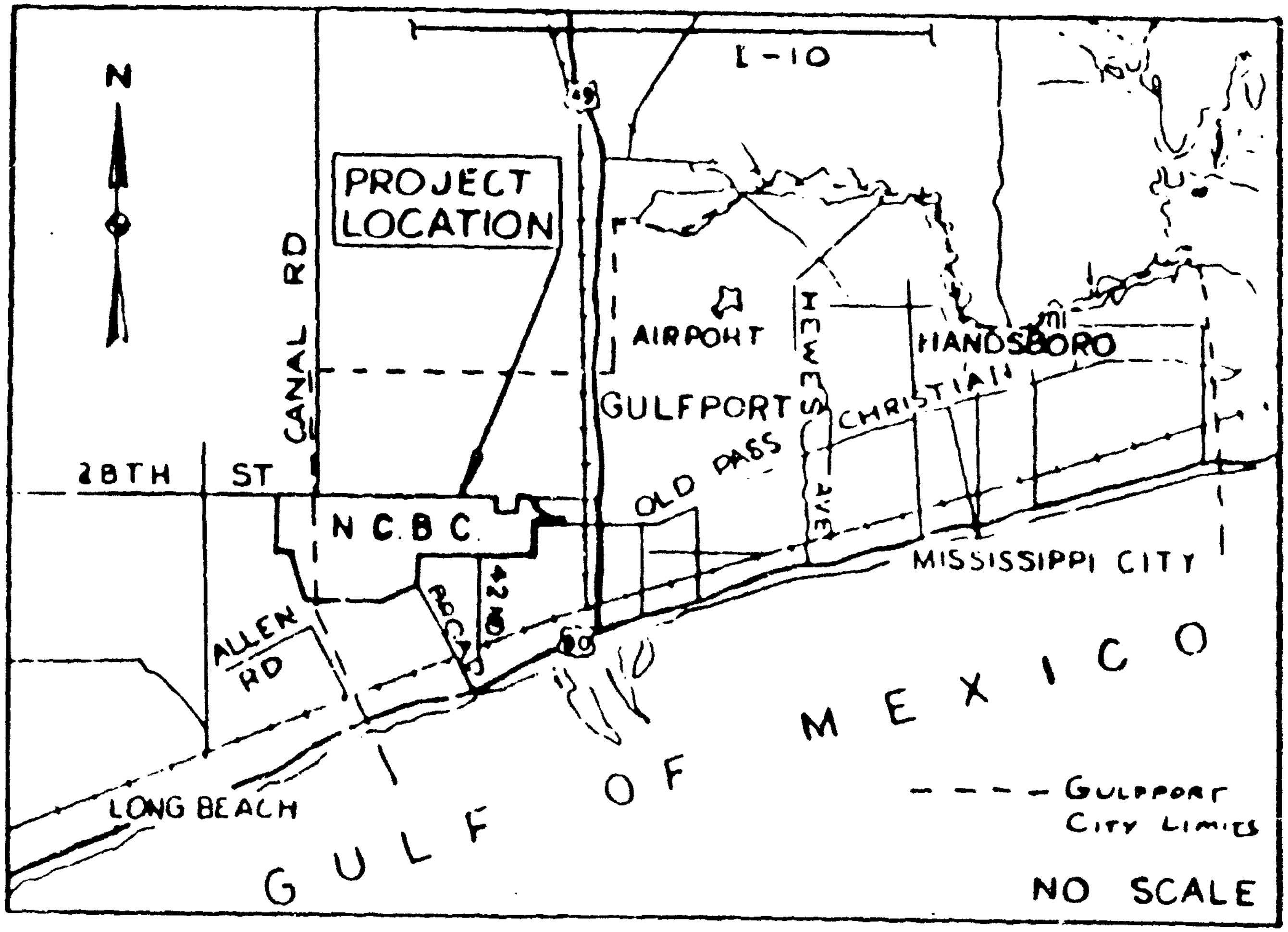

Figure 2. Naval Construction Battalion Center Vicinity Map

C. EGLIN AFB, FL

The Eglin AFB Reservation is located in Northwest Florida and covers approximately 750 square miles. To the south, the Reservation is adjacent to Choctawhatchee Bay and the Gulf of Mexico, while the north and east are bordered roughly by the Yellow River and Alaqua Creek.

The Reservation lies on generally level or gently rolling terrain, all under 300 feet elevation and sloping to sea level on the west and south. It is drained by small tributaries of the Yellow River and Alaqua Creek and by smaller streams that flow directly into Pensacola and Choctawhatchee Bays. The valleys of these streams are steep-sided and end abruptly. The soil of most of the Reservation consists of excessively drained, deep, acid sands of the lakeland series.

Test Area TA C-52A is located in the southeastern part of the Eglin Reservation (Figure 3). It covers an area of approximately 3 square miles (Figure 4) and is a grassy plain, surrounded by a forest stand that is dominated by longleaf pine, sand pine, and turkey oak. The actual site for test operations occupies an area of 2 square miles. This site is cleared and covered mainly by broomsedge, switchgrass and low-growing grasses and herbs.

Test Area C-52A was used to assess the dissemination and deposition characteristics of aerially delivered liquid and particulate materials from spray tanks and other similar systems. Micrometeorological conditions existing below 300 feet over the test area were continuously described by the Automatic Meteorological Data Acquisition and Processing System (AMDAPS). The AMDAPS included wind, temperature, and dew-point sensors on a 300-foot tower at grid center and wind sensors on 12-foot masts located at each of the four corners of the 1-square mile grid. A complex of defoliant grids, intersecting near the central AMDAPS tower and oriented to eight major compass headings, provided 16 discrete sampling grids which could be selected for the most advantageous wind conditions prior to and during missions. These grids employed glass plates and Kromekote cards for physical collection of test materials in droplet form. Each of the 250 permanent sampling stations of the TA C-52A basic grid array employed a wide variety of sampling devices, including the above, but were also equipped with individual commercial power and sequencing control lines for remote operation of automatic vacuum-type samplers which collected small-particle and aerosol test materials. These sampling stations were arranged on 400-foot centers to form the 1-square mile grid (Figure 5). Remote-controlled, battery-operated, portable samplers were also available to gather data in special-purpose grid configurations anywhere in a 10-square mile area.

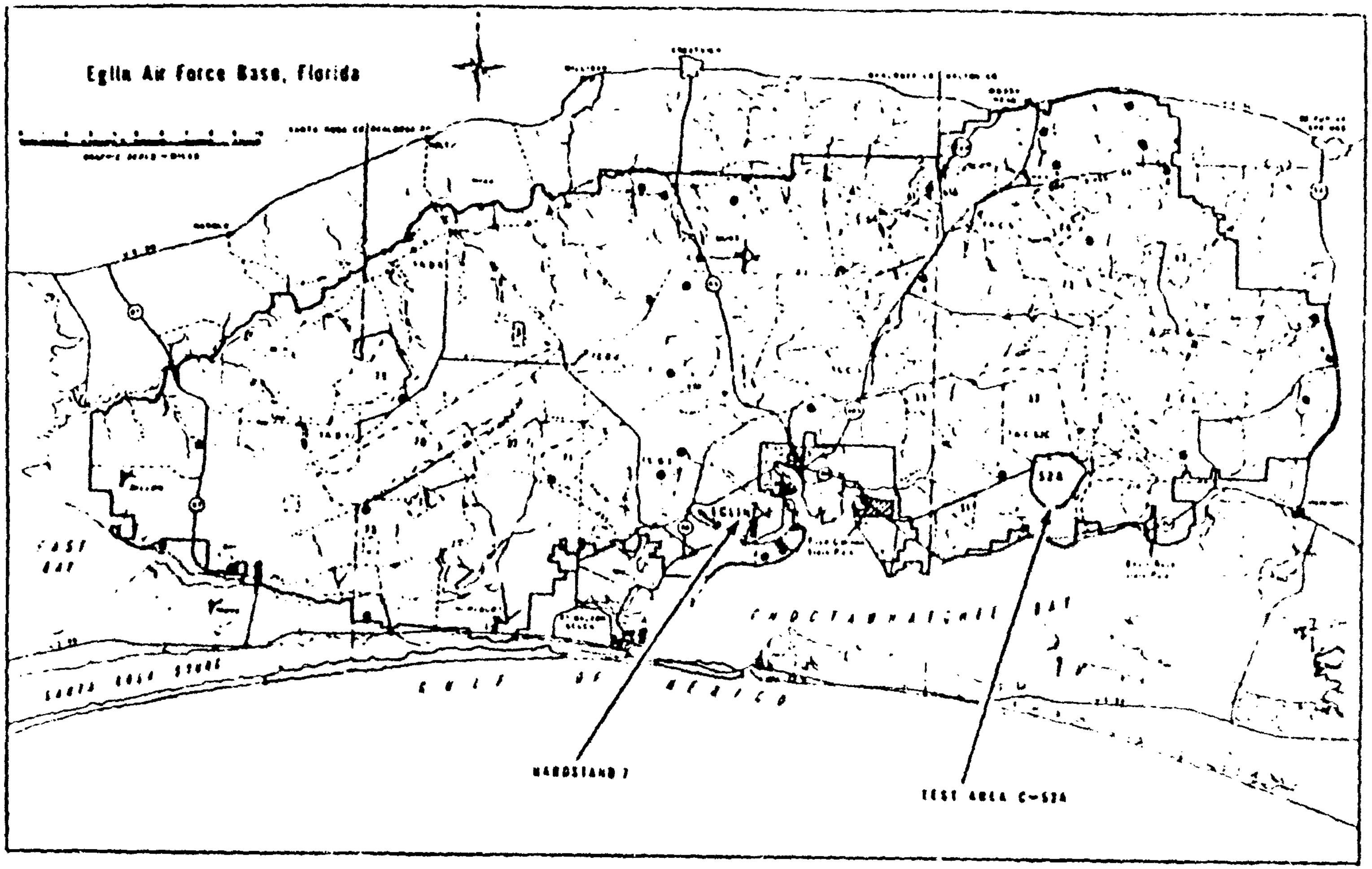

Figure 3. Areas of Study on Eglin Air Force Base, Florida

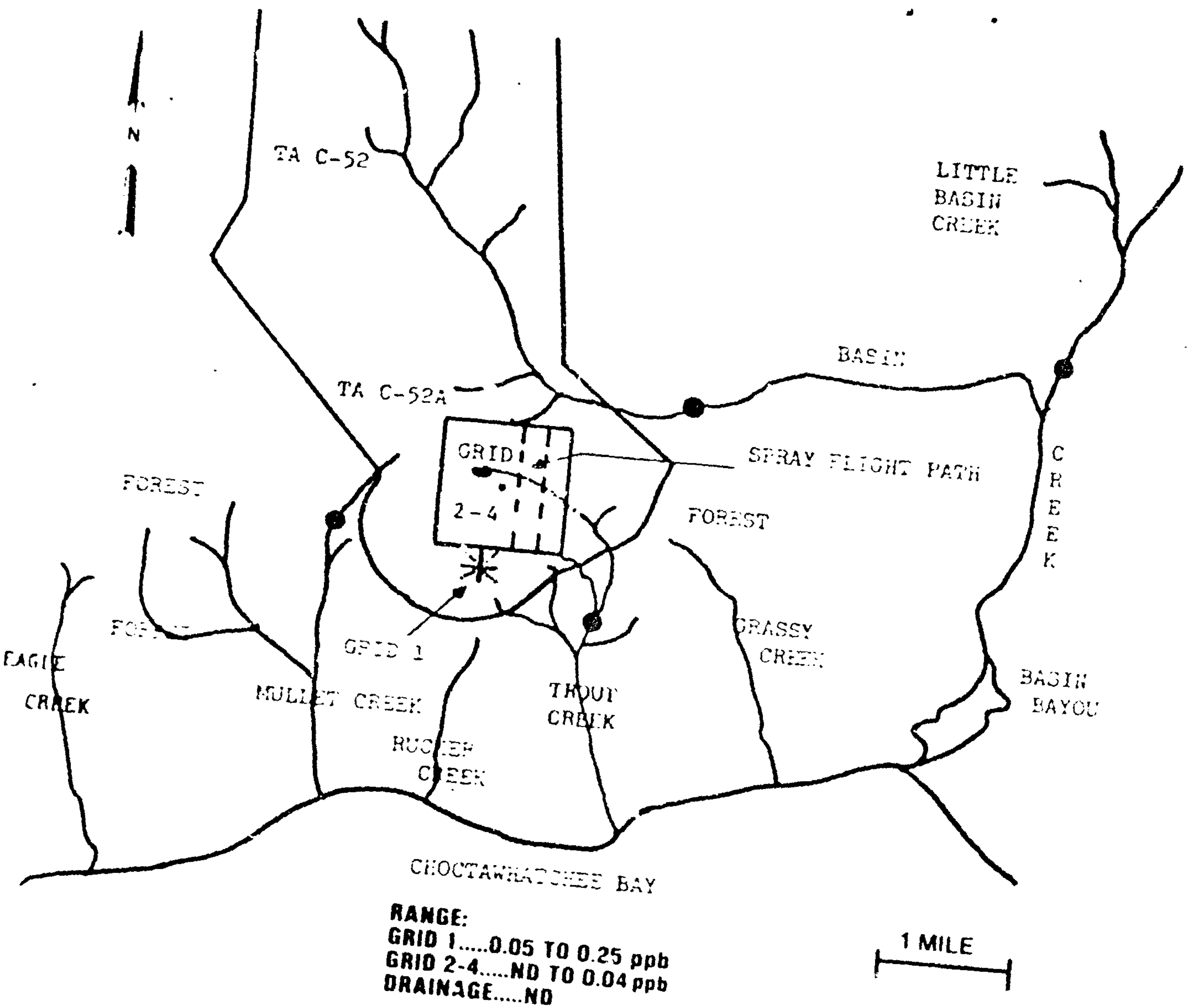

Figure 4. Map of Test Area C-52A, Eglin Air Force Base Reservation, Florida

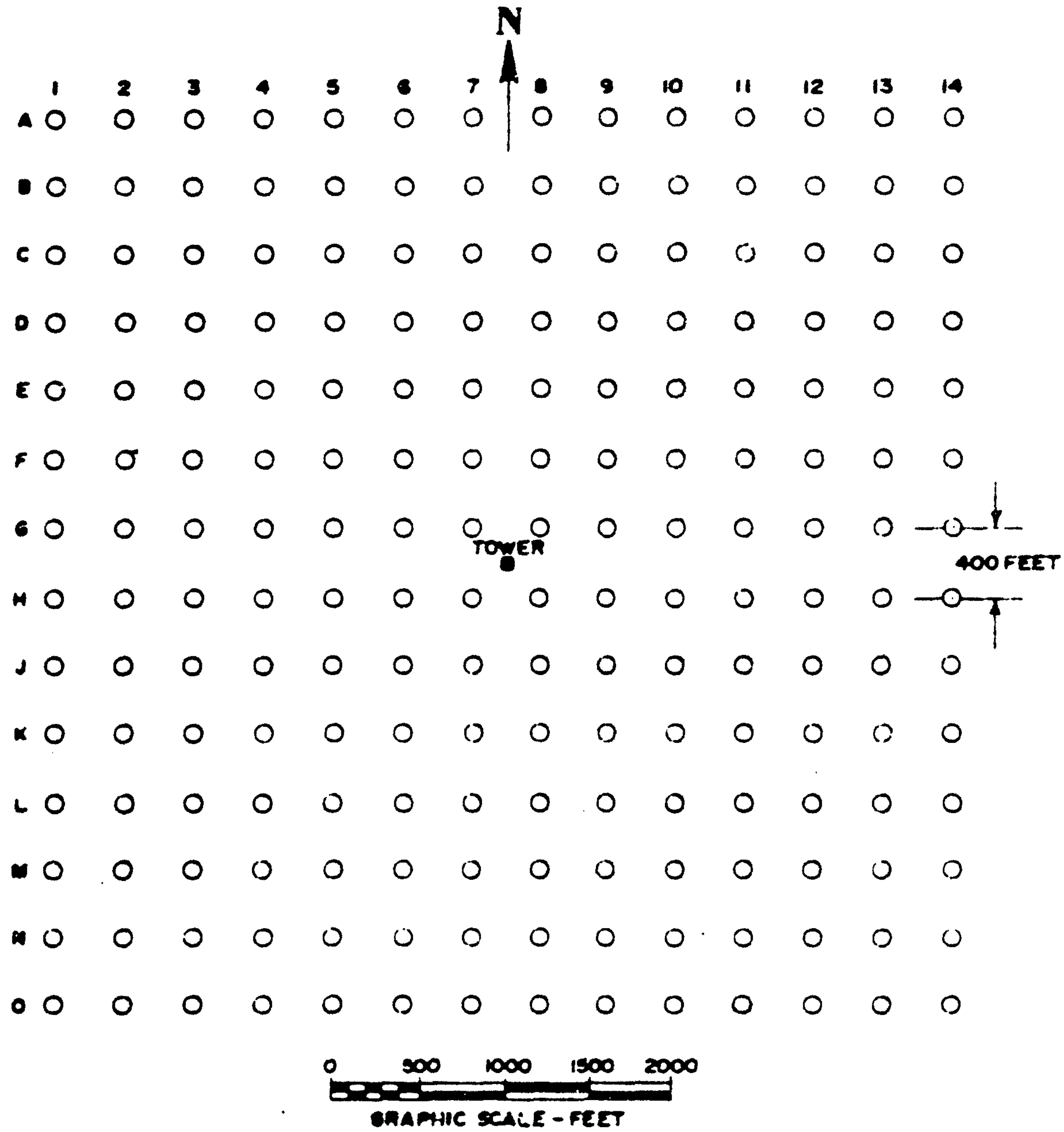

Figure 5. Location of the Permanent Sampling Stations on the 1-Square Mile Grid

Hardstand 7 is an asphalt and concrete aircraft parking area located west of the north-south runway on the main Eglin airdrome (Figures 3 and 6), approximately 65 feet above sea level. Hardstand 7 was one of three areas on Eglin main that had been previously used for storing and loading military herbicides. Hardstand 8 and the east end of Taxiway 9 (Figure 6) were relatively free of dioxin residues in the soil. Hardstand 7 was the most extensively used site for herbicide storage and loading during the 1962 - 1970 spray test program. The soil of this area is sandy, with good drainage properties. Directly behind the hardstand is a ravine (Figure 7) that drops off approximately 30 feet to a small pond, called Hardstand Pond. Because of the packing caused by vehicular traffic and the water-repellent nature of the oil-based herbicide contamination, runoff of excess water caused erosion in some spots, leading to the frequent use of fill dirt. Eventually, an asphalt-covered dike was constructed on the rim of the ravine for soil stabilization and a storm drain was installed for erosion control. Hardstand Pond drains into a small stream which flows north until it enters a manmade reservoir named Beaver Pond. The drainage system eventually flows into Tom's Bayou and Choctawhatchee Bay (Figure 8). Currently, Hardstand 7 is not used for mission support activities. Hardstand Pond is posted to prevent fishing.

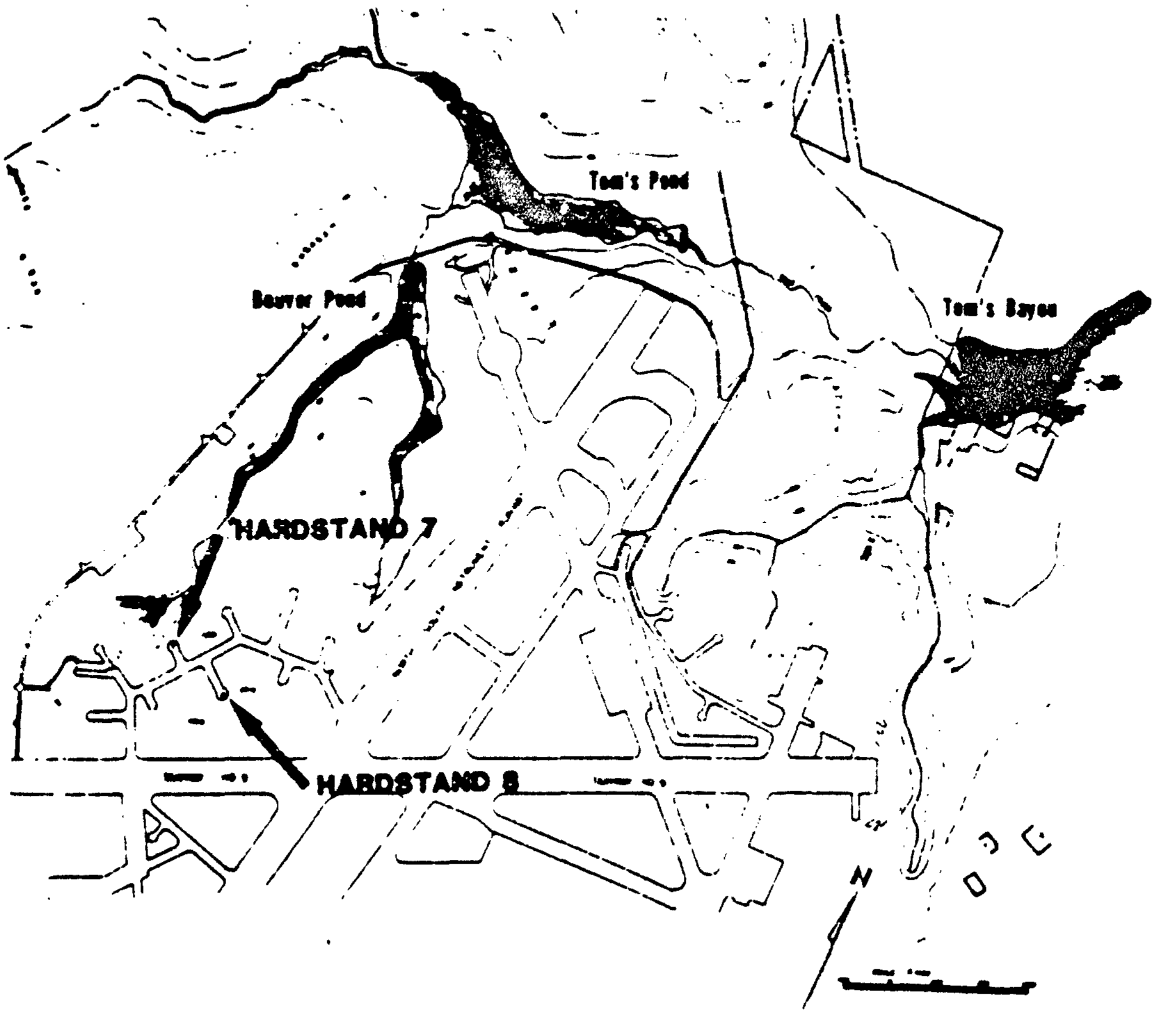

Figure 6. Eglin AFB Herbicide Storage and Loading Sites with Associated Aquatic Drainage Areas

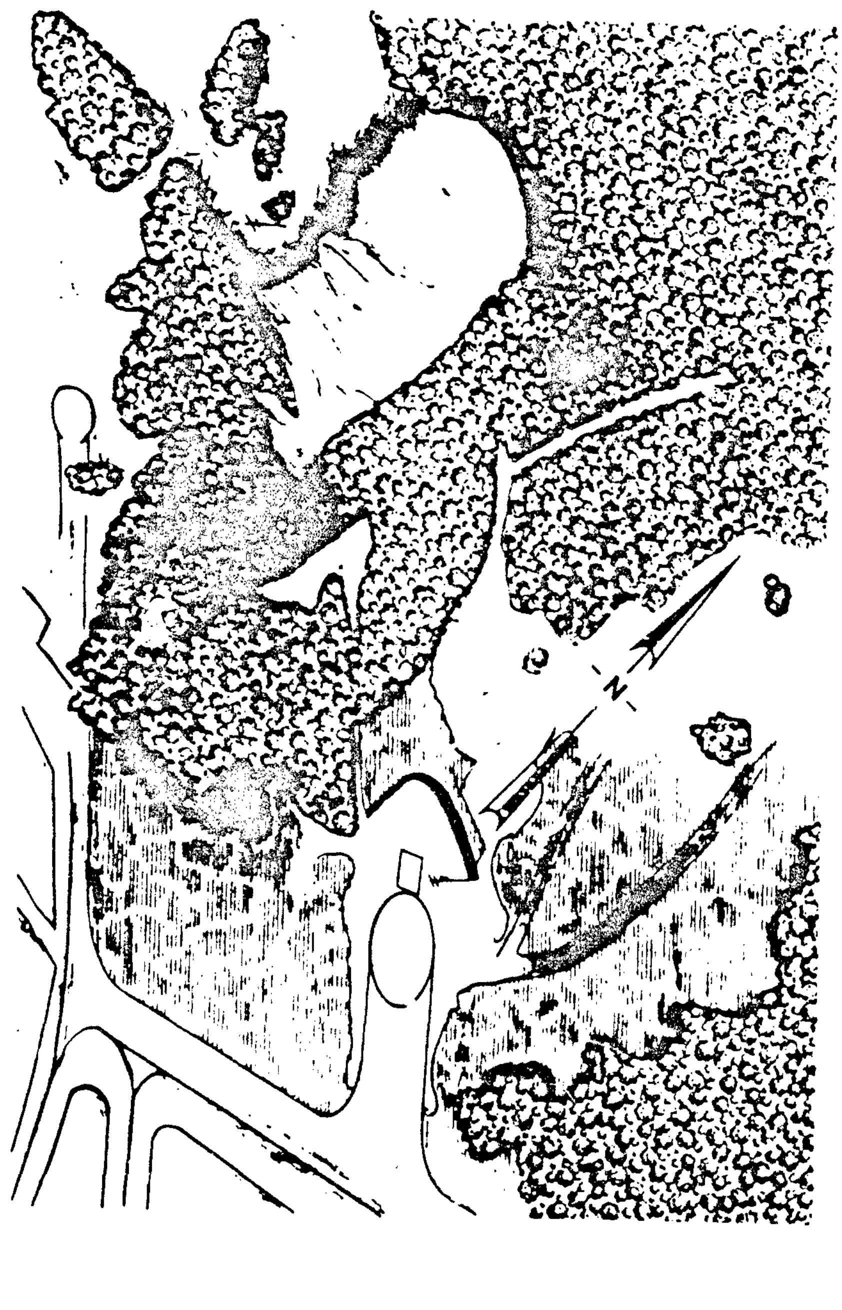

Figure 7. Aerial View of Hardstand 7, Eglin AFB, Florida

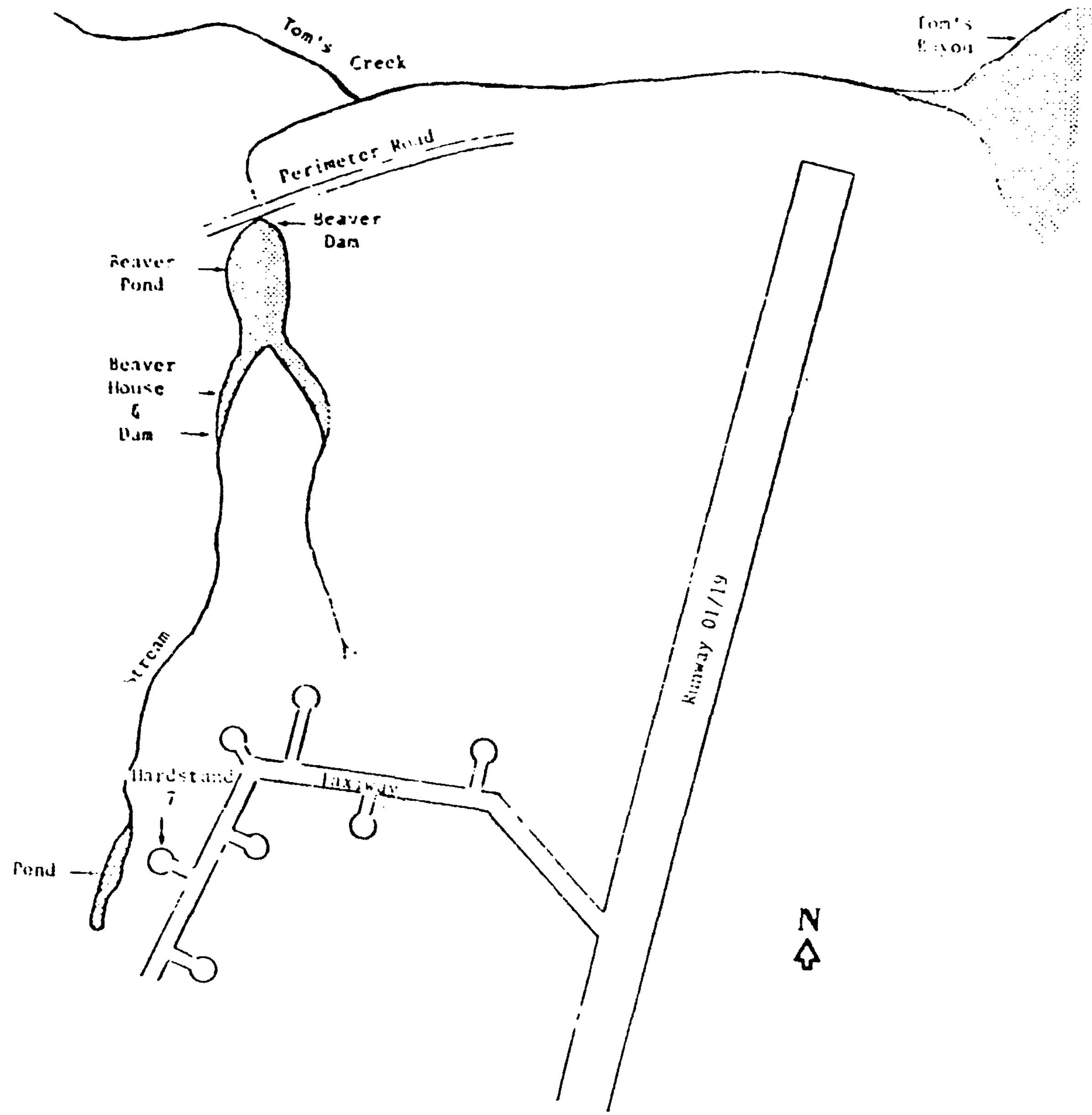

Figure 8. Eglin AFB Hardstand 7 Drainage System Dioxin Data

SECTION III

ENGINEERING AND SERVICES LABORATORY SITE-MONITORING PROTOCOL

A. OBJECTIVE

The objectives for the ESL Monitoring Program are:

1. Determine if offsite migration of dioxin is occurring.

2. Assess the levels of TCDD, 2,4,5-T and 2,4-D, contamination at AF storage/testing facilities.

3. Determine if long-term degradation of the Phenoxy herbicides and the dioxin contaminant occurs.

4. Determine if vertical migration of dioxin takes place.

B. QUALITY ASSURANCE.

To verify the sample precision and accuracy, ESL obtained a series of "known-value" soil specimens from Dr. Robert Harless (USEPA). These samples were submitted "blind" to Brehm Laboratories, Wright State University (WSU) and to California Analytical Laboratories (CAL). The samples supplied to the two laboratories contained interfering substances which would be encountered in the analysis of "real-world" specimens. The results of the Quality Assurance programs are shown in Table 1. Although the two laboratories contracted to provide analyses at different detection limits, an evaluation of the Quality Assurance data reveals that laboratory precision of duplicate specimens is within a factor of 2 or better in all cases. A statistical comparison of the results of representative soil specimen analyses generated by the two contract laboratories can be found in Appendix A. A review of these data indicates that laboratory precision on "real-world" specimens parallels the performance on the EPA-supplied "known-value" specimens.

C. SAMPLING PROCEDURES

The ESL employed a soil-sampling procedure similar to that used by OEHL. The OEHL procedure consisted of collecting a 3-inch cube, 6 inches from the site marker pins. At each sampling, soil was taken from a different "point of the compass," with reference to the marker pin, to insure a fresh and undisturbed sample. The inherent weakness of this sampling protocol was that the concentration of chemicals varied significantly within the spill perimeter. Though this protocol establishes the level and extent of contamination at a specified location, it is useless in evaluating the rate of natural degradation. The ESL sampling protocol uses a single sampling plot, 1 foot square by 3 inches deep, located 6 inches from the marker pin which appears

TABLE 1. EPA STANDARDS[a] - CONCENTRATION IN PARTS PER BILLION

SAMPLE ID	AS PREPARED 2,3,7,8-TCDD	AS PREPARED 2,4-D	AS PREPARED 2,4,5-T	CONTACTOR	AS ANALYZED 2,3,7,8-TCDD	AS ANALYZED 2,4-D	AS ANALYZED 2,4,5-T
EPA-1	0	0	0	WSU	0		
EPA-2	0	50	50	CAL	<0.10	<1000	<1000
EPA-3	0.15	50	50	CAL	<0.10	<1000	<100
EPA-4	0.15	0	0	WSU	0.26		
EPA-5	0.15	0	0	WSU	0.17		
EPA-6	0.25	0	0	CAL	0.14	<80	240
EPA-7	0.25	0	0	WSU	0.39		
EPA-8	0.25	0	0				
EPA-9	0.10	0	0	WSU	0.06		
EPA-10	0.10	50	50	CAL	0.11	<20	6
EPA-11	0.40	50	50	CAL	0.35	<1000	<100
EPA-12	0.40	0	0	WSU	0.23		

[a]Samples consisted of 10 grams of soil prepared and spiked as indicated by Robert Harless, EPA, Research Triangle Park NC.

to be in the most contaminated area. This same sampling plot is resampled on all subsequent sampling dates. The soil was removed, sieved to remove rocks and debris, homogenized, sampled, remixed, and returned to the plot. The main disadvantage of this sampling protocol was the fresh exposure of contaminated soil to sunlight, resulting in a bias caused by accelerated photodecomposition of the dioxin compared to that of undisturbed soil. Five sampling sites were selected at each location to follow the rate of natural degradation. In cases where only the level and extent of contamination were to be determined, the OEHL protocol for soil sample collection was used.

To determine whether or not dioxin was migrating offsite, sediment and biological samples were collected from the NCBC storage site drainage system. Three sediment samples were taken along the perimeter of the seawall at JI and numerous specimens were collected from the drainage systems at Eglin AFB. These samples were collected according to OEHL sampling protocols. The OEHL has established that the primary mode of dioxin movement is through the erosion of contaminated soil into the rainwater drainage systems (References 2 and 3). The likely route of biological species contamination is by direct exposure to contaminated sediments. This route of contamination was previously postulated by Young et al. (Reference 5).

Vertical movement of dioxin in the coral at JI was investigated by extracting coral samples from the vertical wall of a trench created by a backhoe. These samples were collected at specified levels from the surface to a depth of 5 feet. The holes were located at various heavily contaminated areas on the storage site. No depth profile studies have been conducted by the ESL at NCBC. Previous OEHL data have established that the "hardpan" is relatively impervious to water and, presumably, to dioxin (References 2 and 3). Depth profiles at Eglin AFB were conducted with a hand auger or manually dug trench.

D. CHEMICAL ANALYSES

Each soil sample consisted of approximatley 100 grams and was placed into new glass jars, appropriately labeled, and transported to the contract laboratories for analysis. The Brehm Laboratory at Wright State University (WSU), Dayton, OH performed analyses of soil and biological samples for TCDD to a detection limit of 10 picograms/gram (parts per trillion-ppT) using either high-resolution gas chromatagraphy-high-resolution mass spectrometry (HRGC-HRMS) or low-resolution gas chromatagraphy-- high-resolution mass spectrometry (GC-HRMS). California Analytical Laboratories, Inc. (CAL), Sacramento, CA performed analyses of soil samples for TCDD to a detection limit of 100 ppT using high-resolution gas chromatagraphy-low-resolution mass spectrometry (HRGS-MS). CAL also performed all 2,4-D and 2,4,5-T analyses. CAL or WSU performed all analyses for samples collected by ESL from September 1980 to present.

SECTION IV

RESULTS AND DISCUSSION

A. JOHNSTON ISLAND

The mean value for 2,4-D, 2,4,5-T, and 2,3,7,8-TCDD, from samples collected from five of the most frequently sampled sites are listed in Table 2. These sites were originally established by OEHL to monitor the rate of natural degradation of Herbicide Orange and its dioxin contaminants. A statistical comparison of data collected by OEHL (prior to 1979) with current data is not possible due to differences in sampling, analytical protocols, and sample location. A statistical comparison of data analyzed by the current contract laboratories is presented in Appendix A.

Concentrations of Herbicide Orange and the associated dioxin contaminant at the JI Storage Site are highly variable because of localized spills during storage. Herbicide Orange degradation sampling procedures, analytical techniques and environmental factors have also contributed to variability of data. Average TCDD concentrations were plotted on a survey map of the former Herbicide Orange Storage Site (Figure 9). The data plotted were obtained as part of the current monitoring program or from historical data obtained by OEHL before 1979. Insufficient data exist to determine lines of similar concentration for the JI storage area.

The reduction rates for the phenoxy herbicides are listed in Table 3. Rates of reduction are influenced by soil matrix, wind velocity, precipitation, temperature, ultraviolet radiation, and volatility of the herbicide component. Herbicide levels in the Johnston Island soil have decreased approximately 70 percent in a 12-month period.

TABLE 2. SUMMARY OF AVERAGE VALUES FOR HERBICIDE ORANGE RESIDUES AT JI (0-3-INCH DEPTH)

SPILL SITE	CONTACTOR	2,4-D(ppm) LAB AVERAGE	2,4,5-T(ppm) LAB AVERAGE	DIOXIN TCDD(ppb) LAB AVERAGE
1	WSU/CAL[d]			ND(9)[c]
	CAL	<0.6±0.5	<0.1±0.1	<0.1±0.1 ND(4)[b]
	WSU			<0.01±0.00 ND(5)
5	CAL	34±55	67±106	23±16 (3)
	WSU			21±18 (4)
	WSU/CAL			22±16 (7)
10	CAL	1250±443	1083±343	118±83 (4)
	WSU			121±38 (5)
	WSU/CAL			119±60 (9)
12	CAL	509±414	730±427	61±9 (4)
	WSU			41±27 (5)
	WSU/CAL			50±23 (9)
41	CAL	1373±754	1525±369	74±33 (4)
	WSU			79±13 (5)
	WSU/CAL			77±22 (9)

a. NA = No data available.
b. ND = None detected at detection limits of 10 or 100 parts per trillion, respectively.
c. ( ) The number of samples analyzed is in parenthesis.
d. WSU/Cal references split samples.

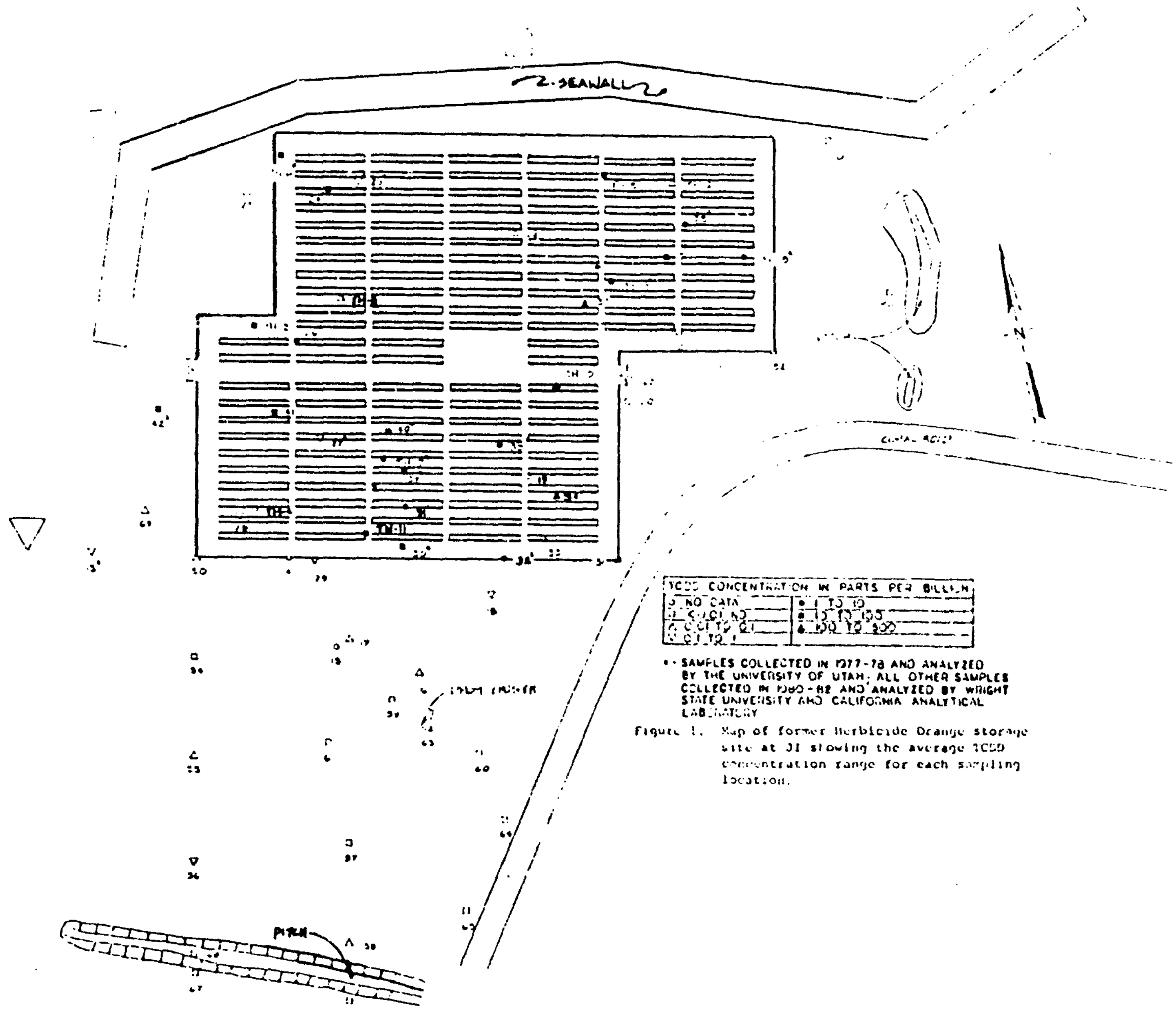

Figure 9. Johnston Island Storage Site Map

TABLE 3. PERCENT REDUCTION OF HERBICIDE LEVELS AT JI

SITE NO.	DATE	2,4-D (ppm)	2,4,5-T (ppm)	TOTAL HERBICIDE (ppm)	DATE	2,4-D (ppm)	2,4,5-T (ppm)	TOTAL HERBICIDE (ppm)	% REDUCTION
1	June 81	<0.01	<0.002	<0.012	May 82	0.21	0.25	0.46	NC
5	June 81	97	190	287	May 82	1.6	3.5	5.1	98
10	June 81	1400	1105	2505	May 82	700	920	1620	35
12	June 81	840	1065	1905	May 82	35	220	255	87
41	June 81	1950	1750	3700	May 82	390	1100	1490	60

NC = Not Calculated

NOTE: Samples collected from depth 0-3 inches at soil surface

(1) Average percent reduction calculated as 70 percent for time period indicated.

Tables 4 and 5 document the results of depth-of-penetration studies conducted in 1982. Maximum depth of penetration was determined at Site TH 42 to be 36 inches at a concentration of 35 parts per trillion. It is difficult to assess the vertical migration rate of TCDD in coral because the initial spill penetration depth is not known. If it is assumed that the initial Herbicide Orange spill was confined to the surface and the spill occurred in 1972, then the approximate vertical migration rate is 3.62 inches per year.

Ocean sediment samples were collected from three sites adjacent to the former storage area and averaged dioxin concentrations of 57 parts per trillion. The low-level positive test results were attributed to the water erosion of coral from the former storage area. The western shoreline is not protected by a retaining wall.

Dioxin concentrations in the first inch of soil are lower than those found at a 3-inch depth. This leads to speculation that either photodegradation takes place, wind erosion moves "clean" soil over the contaminated site, or that dioxin is carried to greater depths in the soil via precipitation. Further research must be conducted to identify the cause of the stated variations in the data.

B. NAVAL CONSTRUCTION BATTALION CENTER (NCBC)

Sampling points at the NCBC Storage Site are identified in Figure 10. A summary of current herbicide and dioxin concentrations at the former storage site is given in Table 6. As a result of localized spills from leaking drums, dioxin concentrations are variable and range from 0.2 to 263 ppb. No depth-of-penetration studies have been conducted past the artifical hardpan. Data collected by OEHL before 1979 (Reference 2 and 3) suggest that penetration of Herbicide Orange and TCDD past the current stablilized zone would be negligible.

Percent reduction calculations (Table 7) indicate that concentrations of the phenoxy herbicides have decreased approximately 60 percent over the stated time period. Environmental factors influencing herbicide reduction have been stated previously in this report.

The NCBC drainage system, a series of easement basins and ditches, provides drainage for the former storage site and the surrounding area (Figures 11 and 12). Previous studies (References 2 and 3) documented dioxin contamination in the drainage system. The mean dioxin concentration derived from current data is presented in Table 8. An evaluation of the data indicates a pattern of dilution; specimens collected closest to the former storage site show higher concentrations of dioxin than those collected farther downstream. It appears likely that biological specimens collected from the drainage ditch habitat became contaminated by intimate contact with dioxin - contaminated soils

TABLE 4. DEPTH-OF-PENETRATION DATA FOR HERBICIDE ORANGE RESIDUES FOR SELECTED SITES AT JI

SPILL SITE	DATE	CONTRACTOR	DEPTH (IN)	2,4-D(ppm)	2,4,5-T(ppm)	DIOXIN TCDD(ppb)	AVERAGE TCCD(ppb)
TH 10	Oct 82	CAL/WSU	0-1.5	1570	6090	82/172	127 ± 64
			1.5-3	1110	3740	88/117	103 ± 21
			3-6	890	3770	43/69	56 ± 18
			6-9	871	3150	27/39	33 ± 8
			9-12	601	2110	30/36	33 ± 4
			12-15	599	2140	23/32	28 ± 6
		WSU	15-18			17	
			18-21			15	
			21-24			6	
			27-30			0.04	
			33-36			<0.01 ND[b]	
			45-48			<0.01 ND	
			57-60			<0.01 ND	

a - CAL/WSU references split samples.

[b]ND - Not detected by the indicated detection limits.

TABLE 4. DEPTH-OF-PENETRATION DATA FOR HERBICIDE ORANGE RESIDUES FOR SELECTED SITES AT JI (CONCLUDED)

SPILL SITE	DATE	CONTRACTOR	DEPTH (IN)	2,4-D(ppm)	2,4,5-T(ppm)	DIOXIN TCDD(ppb)	AVERAGE TCDD(ppb)
TH 37	Oct 82	WSU	0-1			31	
			1-3			75	
			3-6			41	
			6-9			28	
			9-12			17	
			12-15			2	
			15-18			0.17	
			18-21			0.14	
			21-24			0.14	
			27-30			0.015	
			33-36			0.035	
			45-48			<0.01 ND	
			57-60			<0.01 ND	

TABLE 5. DEPTH-OF-PENETRATION DATA FOR DIOXIN FOR SELECTED LIGHT-SPILL SITES AT JI

SPILL SITE	DATE	CONTRACTOR	DEPTH (IN)	DIOXIN TCDD(ppb)	
TH-5	Oct 82	WSU	0-1	2.8	
			1-3	2.2	
			3-6	0.12	
			6-9	0.07	
			9-12	<0.01	ND[a]
			12-15	0.19	
			15-18	<0.01	ND
			18-21	<0.01	ND
			21-24	<0.01	ND
42	Oct 82	WSU	0-1.5	24	
			1.5 3	21	
			3-6	1.5	
			6-9	0.16	
			9-12	0.93	
			12-15	0.06	
			15-18	<0.01	ND
			18-21	<0.01	ND
			21-24	<0.01	ND
			27-30	<0.01	ND
			33-36	<0.01	ND

[a]ND - Not detected at the indicated detection limit.

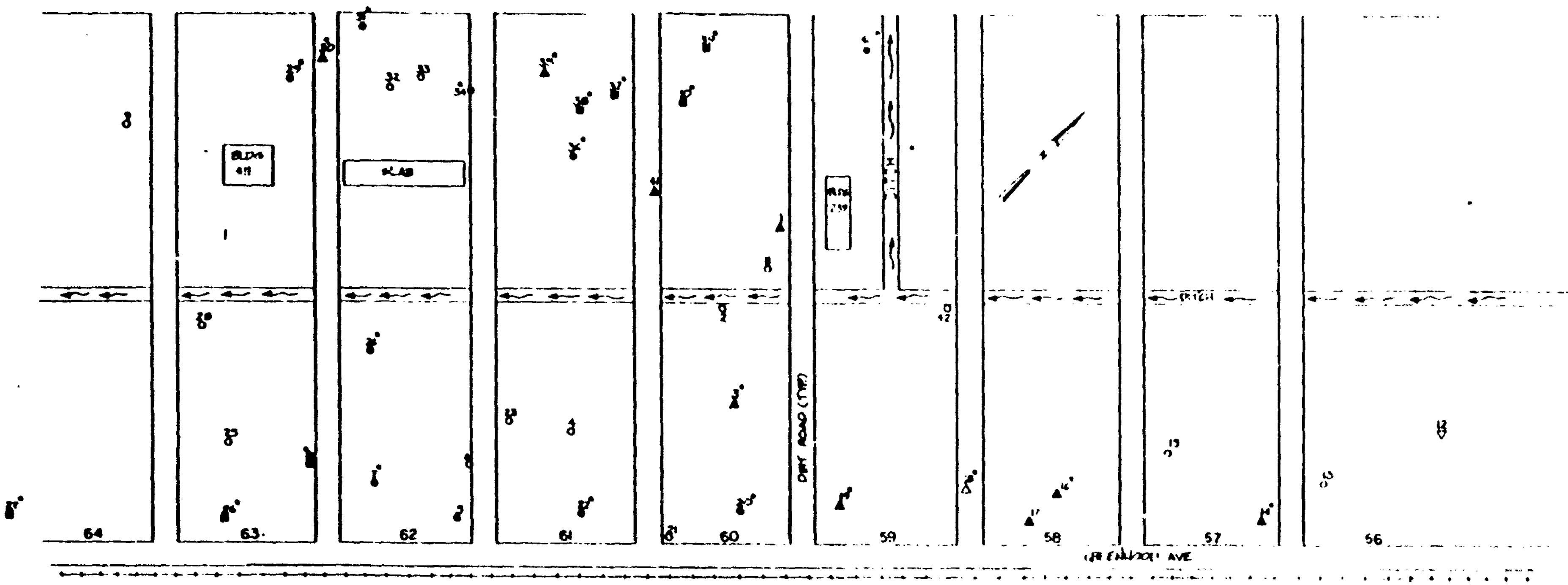

Figure 10 Map of former Herbicide Orange storage site at NCBC showing the average TCDD concentration range for each sampling location.

TCDD CONCENTRATION IN PARTS PER BILLION	
○ NO DATA	● 1 TO 10
ō <0.01 ND	■ 10 TO 100
△ 0.01 TO 0.1	▲ 100 TO 500
▽ 0.1 TO 1	

* - SAMPLES COLLECTED IN 1977-78 AND ANALYZED BY THE UNIVERSITY OF UTAH; ALL OTHER SAMPLES COLLECTED IN 1980-82 AND ANALYZED BY WRIGHT STATE UNIVERSITY AND CALIFORNIA ANALYTICAL LABORATORY

Figure 10. Map of Former Herbicide Orange Storage Site at NCBC Showing the Average TCDD Concentration Range for Each Sampling Location

TABLE 6. SUMMARY OF AVERAGE VALUES FOR HERBICIDE ORANGE RESIDUES AT NAVAL CONSTRUCTION BATTALION CENTER

SPILL SITE	CONTRACTOR	2,4-D(ppm) LAB AVERAGE	2,4,5-T(ppm) LAB AVERAGE	TCDD(ppb) LAB AVERAGE
1	CAL	301±326	394±475	194±32 (4)[a]
	WSU			144±22 (5)
	WSU/CAL[b]			166±36 (9)
5	CAL	465±191	1820±255	1.3±1.6 (2)
	WSU			2.2±0.6 (3)
	WSU/CAL			1.8±1.1 (5)
12	CAL	<0.7±0.6	<0.4±0.5	<0.09±0.02 (3)
	WSU			0.2±0.3 (5)
	WSU/CAL			0.2±0.2 (8)
17	CAL	2999±2368	2968±1036	207±80 (4)
	WSU			263±113 (5)
	WSU/CAL			238±98 (9)
41	CAL	1703±1595	1343±657	138±42 (4)
	USU			157±73 (5)
	WSU/CAL			148±59 (9)

a - The number of samples analyzed is in parentheses.
b - WSU/CAL references split samples.

TABLE 7. PERCENT REDUCTION OF HERBICIDE LEVELS AT NCBC (1981-1982)

SITE NO.	DATE	2,4-D (ppm)	2,4,5-T (ppm)	TOTAL HERBICIDE (ppm)	DATE	2,4-D (ppm)	2,4,5-T (ppm)	TOTAL HERBICIDE (ppm)	% REDUCTION
1	Nov 81	130	200	330	April 82	22	74	96	78
5	Nov 81	600	2000	2600	April 82	330	1640	1970	24
12	Nov 81	<0.01	<0.01	<0.01	April 82	<1	<1	<1	NC
17	Nov 81	5000	3700	8700	April 82	796	2770	3566	59
41	Nov 81	3050	1850	4900	April 82	110	570	680	86

NC = Not Calculated

NOTE: Samples collected from depth of 0-3 inches at soil surface

(1) Average percent reduction calculated as 61% for time period indicated.

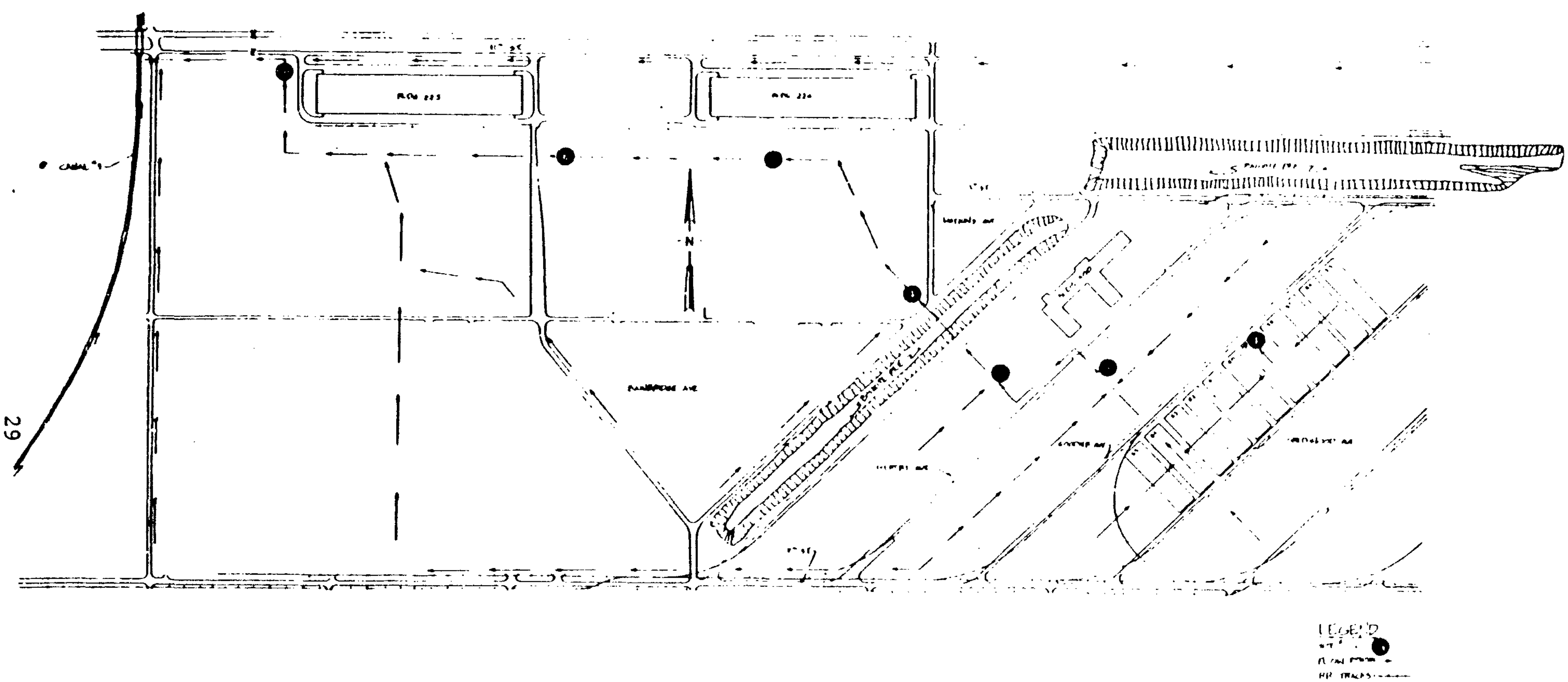

Figure 11. Map Showing Aquatic Sampling Sites 1 Through 7, Their Relationship to the Herbicide Orange Storage Area and the Aquatic System Flow Pattern at NCBC

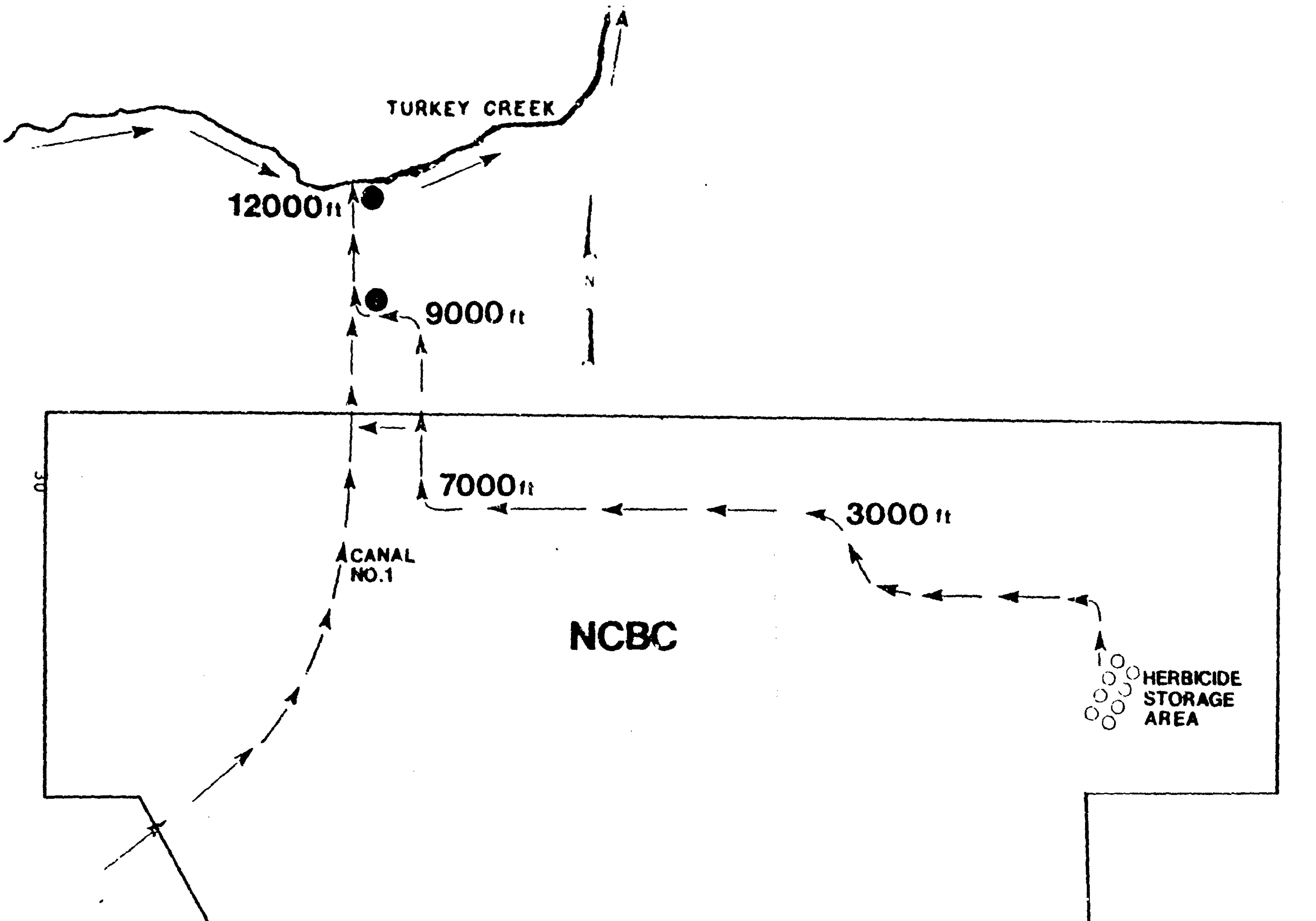

Figure 12. NCBC Storage Site Map

TABLE 8. AVERAGE DIOXIN LEVELS IN THE DRAINAGE DITCH SYSTEM OF THE NAVAL CONSTRUCTION BATTALION CENTER

DRAINAGE SITE	DATE	SAMPLE TYPE	DIOXIN TCDD AVERAGE (ppb)
1	80-82	SEDIMENT	1.14 ± 0.76
		BIOLOGICAL	1.12 ± 0.77
2	80-82	SEDIMENT	0.43 ± 0.44
		BIOLOGICAL	1.23 ± 1.65
3	80-82	SEDIMENT	<0.02 ± 0.01
		BIOLOGICAL	<0.04 ± 0.04
4	80-82	SEDIMENT	<0.03 ± 0.03
		BIOLOGICAL	<0.11 ± 0.09
5	80-81	SEDIMENT	<0.02 ± 0.01
		BIOLOGICAL	0.02
6	80-82	SEDIMENT	<0.02 ± 0.01
		BIOLOGICAL	0.11 ± 0.12
7	80-82	SEDIMENT	<0.08 ± 0.08
		BIOLOGICAL	0.05 + 0.01
8	80-82	SEDIMENT	0.03 ± 0.02
		BIOLOGICAL	0.05

TABLE 8. AVERAGE DIOXIN LEVELS IN THE DRAINAGE DITCH SYSTEM OF NAVAL CONSTRUCTION BATTALION CENTER (CONCLUDED)

DRAINAGE SITE	DATE	SAMPLE TYPE	DIOXIN TCDD AVERAGE (ppb)
9	80-81	SEDIMENT	<0.03 ± 0.02
		BIOLOGICAL	<0.01 ND[a]

NOTE: All analyses conducted by Brehm Laboratories.

[a]ND - Not detected at the indicated detection limit.

and sediments. Although a filtration sedimentation system has been constructed to contain dioxin - contaminated soils onsite, it has not been possible to evaluate its effectiveness.

C. EGLIN AFB, TEST RANGE C-52A

All data reported for Eglin AFB are for samples collected between 1980 and 1982. The sampling program for Eglin AFB was designed around three primary sampling goals or priorities:

1. To assess the migration of dioxin from the test and loading sites.

2. To determine the level and extent of 2,4-D, 2,4,5-T, and dioxin contamination on and near the test and loading sites.

3. To determine if vertical movement of dioxin was occurring.

Extensive sampling of the water drainage systems was conducted to assess the potential migration of dioxin from the test and loading sites. Sediment and biological samples were taken from points where the TA C-52A drainage creeks (Mullet, Trout, and Basin) exit the Eglin Reservation and from the headwaters adjacent to the test grids on TA C-52A. All samples were negative for dioxin at a detection limit of 10 ppT. Soil samples collected from the tree line surrounding TA C-52A and samples collected 1000 feet north, south, east, or west from the corners of the 1-mile square test grid and Grid 1 were also negative for dioxin at a detection limit of 10 ppT. These data give a very high degree of assurance that the dioxin is contained on the test site.

Since the herbicides were sprayed somewhat uniformly over the test grid, as compared to the nonuniformity of the spills in the storage and loading areas, the sampling protocol for the test grid was designed to determine the average dioxin level. The test grid was divided into five sampling areas based on the aircraft spray patterns employed. The 1-mile square grid was divided into four quadrants (Figure 13). Grid 1 was the fifth sampling area, based on the fact that it received the highest application of the herbicides. On each sampling date, all sampling points within Grid 1 were sampled. For the 1-mile square area all perimeter sampling points were eliminated, as previous tests for dioxin were negative (i.e., A1-A14, O1-O14, B1-N1 and B14-N14). Of the remaining 36 sampling points within each quadrant, 12 were selected randomly on each sampling date. For Quadrants 1 and 2, the actual sampling locations were 50 feet north of each marker. For Quadrants 3 and 4, the sampling locations were 50 feet south of each marker. These locations were selected to minimize the effects on sample composition from vehicular traffic along the roads near the sampling markers. Grid 1 samples were collected near to the marker. In all cases, a 3-by 3-by 3-inch cube of soil was removed, sieved to eliminate rocks

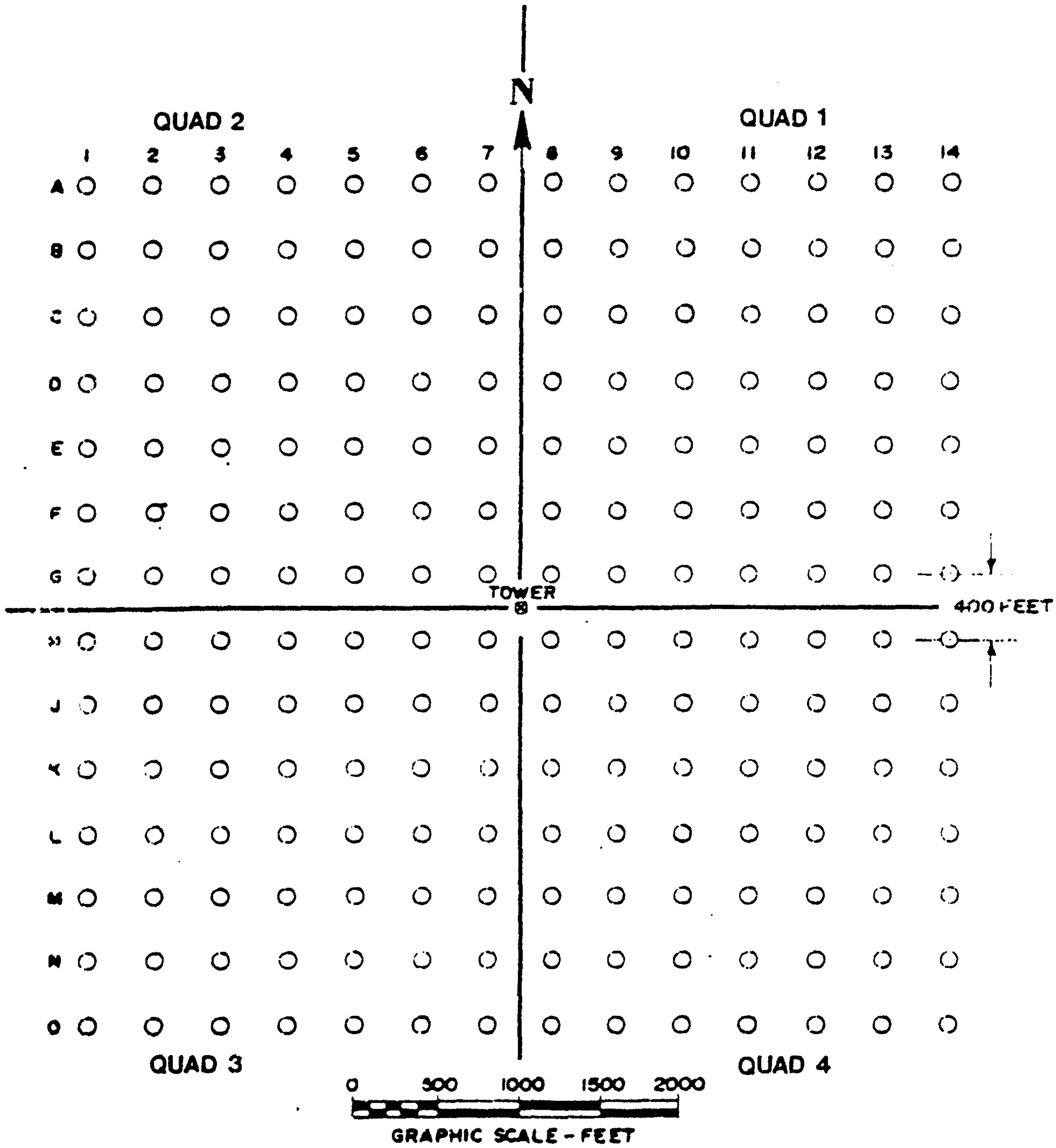

Figure 13. Location of the Permanent Sampling Stations on the 1-Square-Mile Grid

and debris and thoroughly mixed. A uniform volume of soil was then removed and placed in a new glass container. When all samples from one test area were collected, they were thoroughly mixed and a "pooled" sample of soil was placed in a new glass jar and appropriately labeled. Table 9 gives the average dioxin values for all samples collected between 1980 and 1982. The average values are very low. The highest dioxin levels, as expected, were found on Grid 1. Reductions in surface TCDD levels have occurred since the termination of aerial spray testing in 1968. These reductions are probably due to photo degradation. Table 10 gives the results of a depth study conducted on Grid 1. The sampling site was the center point of Grid 1. No dioxin was detected below a depth of 6 inches.

D. EGLIN AFB HARDSTAND 7

To determine if migration of dioxin from Hardstand 7 had occurred, sediment and biological samples were taken from the point where Tom's Creek exits Eglin AFB. All samples have been negative for dioxin at a detection limit of 10 ppT. All samples collected from Beaver Pond have been negative for dioxin at a detection limit of 10 ppT except for one sediment sample analyzed at 25 ppT. The average value for both sediment and biological samples collected from Hardstand Pond was 80 ± 70 ppT.

Figure 14 shows Hardstand 7 with the locations of known herbicide storage sites and sampling locations. Much of the area immediately surrounding this hardstand was contaminated with herbicide due to accidental spills during loading operations, leaking drums, and purging of the spray system before and after missions. A pit was dug in 1969 (according to the best available information) to the southwest of the hardstand (Figure 14) as a temporary means of preventing the excess herbicides from entering the stream in back of the hardstand. After several months of use, the pit was filled with soil.

Table 11 lists the data on samples taken from the Hardstand 7 area. As one moves out radially from the hardstand, dioxin levels drop off rapidly to nondetectable at 125 feet, with a detection limit of 10 ppT. Depth profiles at D1 and K1 show significant TCDD levels at a depth of 9 feet. The very high dioxin levels at 9 feet for site D1 are probably due to the pit that was located in this area, as discussed earlier. The higher levels of TCDD in the 12- to 36-inch depths at K1 may indicate the slow movement of dioxin through the soil.

TABLE 9. AVERAGE DIOXIN LEVELS ON TEST AREA C-52A AT EGLIN AFB

DATE	CONTRACTOR	SAMPLING AREA	AVERAGE TCDD(ppb) (DIOXIN)
81-82	WSU	QUADRANT 1	<0.01 ND[a]
		QUADRANT 2	0.01 $\pm$ 0.01
		QUADRANT 3	0.03 $\pm$ 0.01
		QUADRANT 4	0.01 $\pm$ 0.01
		GRID 1	0.15 $\pm$ 0.10

[a]ND - Not detected at the indicated detection limit.

TABLE 10. DEPTH-OF-PENETRATION DATA ON TCDD FOR GRID 1, TEST AREA C-52A AT EGLIN AFB

DATE	CONTRACTOR	DEPTH (INCHES)	AVERAGE TCDD(ppb) (DIOXIN)
May 82	WSU	0-1	0.05
		1-3	0.17
		3-6	0.10
		6-12	<0.01

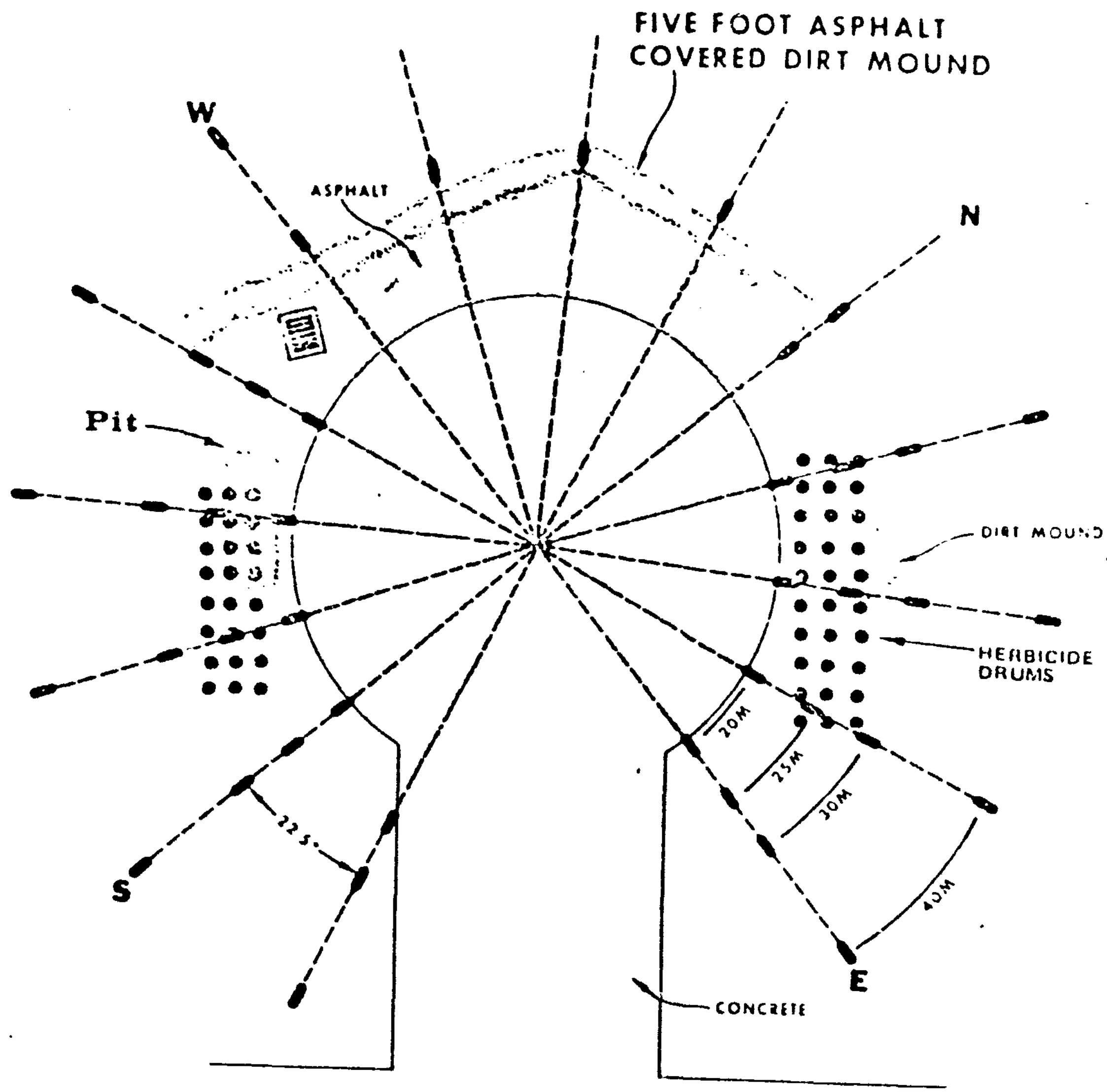

Figure 14. Locations of Known Herbicide Orange Storage Sites and Disposal Pit on Hardstand 7

TABLE 11. DIOXIN DATA FOR SELECTED SITES ON HARDSTAND 7 AT EGLIN AFB

SAMPLING SITE	DATE	CONTRACTOR	DEPTH (IN)	DIOXIN TCDD(ppb)	
3 FEET FROM SURFACE D RADIAL[a]	Dec 81	WSU	0-3	46	
	May 82	WSU	0 3	22.5	
50 FEET FROM SURFACE D RADIAL[a]	Dec 81	WSU	0-3	0.025	
	May 82	WSU	0-3	0.02	
125 FEET SOUTH WEST D RADIAL[a]	Nov 82	WSU	0-3	<0.01	ND[b]
			3-6	<0.01	ND
			6-9	<0.01	ND
			9-12	<0.01	ND
			15-18	<0.01	ND
D1[a]	May 82	WSU	0-3	138	
			3-6	159	
			9-12	126	
			21-24	46	
			33-36	15	
			45-48	96	
			69-72	102	
			105-108	136	
K1[a]	May 82	WSU	0-3	58	
			3-6	58	
			9-12	72	
			21-24	115	
			33-36	92	
			45-48	37	
			69-72	37	
			105-108	10	

[a] - Indicates sampling site location, see Figure 13.

[b]ND - Not detected at the indicated detection limit.

SECTION V

CONCLUSIONS

Environmental monitoring and evaluation studies of areas on Johnston Island, the Naval Construction Battalion Center, and Eglin AFB, previously used for the storage, loading and testing of HO from 1962 through mid-1977 are reported here for 1980 through 1982. The following conclusions are from those studies:

A. JOHNSTON ISLAND

1. Approximately 10 acres of the former storage and work area are contaminated with HO and its associated dioxins.

2. Levels of 2,4-D and 2,4,5-T have decreased approximately 70 percent since 1981.

3. Because of the recalcitrance of dioxin, limited amounts of sampling data and large variability in that data, no accurate estimate of dioxin persistence is possible.

4. Dioxin contamination was detected to depths of 3 feet in heavy spill areas.

5. Dioxin contamination of the ocean sediments was observed only along the west wall where coral erosion occurred due to the lack of a protective sea wall. Three samples tested positive for dioxin at part per trillion levels.

6. Low levels of dioxin contamination were observed outside the former storage area. These lightly contaminated areas occurred where drum storage, transportation, and crushing operations were conducted. Light contamination may have resulted from wind erosion of the former storage area.

B. NAVAL CONSTRUCTION BATTALION CENTER

1. Approximately 2-4 acres of the 12-acre former storage site are contaminated with HO and its associated dioxins.

2. Levels of 2,4-D and 2,4,5-T have decreased approximately 60 percent since 1981.

3. Based on available data, no accurate estimate of dioxin persistence is possible.

4. Dioxin levels in the surface-water drainage system (sediment and biological samples) are two orders of magnitude below those found in the soil of the former storage site. The

dioxin level (1980-1982 data) decreases significantly with distance from the former storage site and was nondetectable at the 12,000 foot point, to a detection limit of 10 ppT. Low levels of dioxin (<50 parts per trillion) have been detected 2000 feet off-site in sediment and biological specimens. Sediment and biological contamination were comparable for each sampling site.

C. EGLIN AFB

1. Dioxin contamination appears to be contained and controlled.

2. The 1-mile square grid has very low levels of dioxin contamination (30 ppT or less). The average value for Grid 1 is 150 ppT.

3. Dioxin depth penetration on TA C-52A has not been demonstrated.

4. Dioxin contamination (well in excess of EPA action level) exists in the immediate vicinity of Hardstand 7.

5. Dioxin contamination was observed at depths of 9 feet at the periphery of Hardstand 7. This depth of penetration has been attributed to heavy herbicide spills.

6. Both surface and depth contamination by dioxin decreased significantly with distance from Hardstand 7.

D. GENERALIZED CONCLUSIONS

1. The movement of dioxin from the storage, loading, and test sites seems to occur primarily through soil erosion, caused by water, wind, or human activity.

SECTION VI

RECOMMENDATIONS

A. JOHNSTON ISLAND

1. Continue to limit access to the contaminated area and prevent motor vehicle traffic from crossing the area and potentially "tracking" dioxin-contaminated soil particles to other parts of the island.

2. Construct a seawall on the west side of the former storage site to prevent further erosion of the coral into the ocean.

3. Continue to monitor the site for natural degradation of dioxin.

4. Continue to investigate dioxin depth penetration at the former storage site to verify that vertical movement is occurring and at what rate.

5. The ESL should work closely with the DNA to develop reclamation protocols for returning the storage area to full and beneficial use.

6. Continue to map the area to better define both the horizontal and vertical levels of dioxin contamination.

7. Continue research to determine acceptable and cost-effective methods for returning the storage area to full and beneficial use.

B. NAVAL CONSTRUCTION BATTALION CENTER

1. Evaluate site security and increase it, if necessary, to prevent motor vehicle traffic from entering the area and potentially "tracking" dioxin-contaminated soil particles to other parts of the installation.

2. Evaluate the effectiveness of the existing system to prevent water erosion of the storage site soil wherever possible. Regularly maintain drainage system erosion control devices.

3. Allow native vegetation to continue to grow and spread in the storage area and drainage ditches to help prevent wind and water erosion.

4. Continue to monitor the drainage ditch system on a semiannual basis to confirm that migration of dioxin from the former storage site is not occurring.

5. Conduct additional surface water sampling and analyses on the storage site drainage system and in the Turkey Creek receiving waters.

6. Evaluate the sampling interval for sites used to follow the rate of natural degradation of dioxin.

7. Conduct a depth profile study to verify that soil penetration by dioxin is occurring.

8. Collect additional water samples from the drainage ditch system servicing the former storage site to verify that surface water contamination by dioxin is not occurring.

C. EGLIN AFB TEST AREA C-52A

1. Evaluate the effects of wind/water erosion on transport of dioxin.

2. Grid 1 usage should be restricted to essential mission activities. Reasonable and prudent efforts should be undertaken to prevent erosion-causing activities.

D. EGLIN AFB HARDSTAND 7

1. Erect a chain-link fence around Hardstand 7, Hardstand Pond and Beaver Ponds. "Off Limits" and "No Fishing" signs should be posted and appropriately displayed.

2. A vegetative ground cover should be planted on the ravine slope adjacent to and northwest of Hardstand 7 to control erosion.

3. Maintain the berm at Hardstand 7 in a good and effective state of repair.

4. Continue to monitor the drainage system leading from Hardstand 7 to confirm that migration of TCDD from the former storage and loading site is not occuring.

5. Collect and analyze sediment and biological samples from the entrance of Tom's Creek to Tom's Bayou.

6. Collect depth profile sediment samples from Hardstand Pond.

7. Conduct a depth study adjacent to Hardstand 7 to determine if TCDD penetration is occurring. Such a study should be conducted at a location other than D1 because of the pit dug in this area in 1969 (Figure 13). A second depth study should be

conducted in the pit area to determine levels and depths of contamination resulting from operation of this catchment pit in 1969.

8. Conduct surface water sampling and analyses to confirm that TCDD is not being transported offsite.

General Recommendations (All Sites)

1. Expand current monitoring/research program to incorporate views presented in the Environmental Protection Agency's National Dioxin Strategy.

2. Map dioxin concentrations in soil at all sites to establish boundaries for ultimate reclamation activities.

3. Request that AF Surgeon General establish a site safety procedure for all personnel working on/in dioxin - contaminated areas.

APPENDIX A

STATISTICAL EVALUATION OF LABORATORY DATA*

Quality control was checked by submitting identical samples to both contract laboratories (California Analytical Laboratories (CAL) and Wright State University (WSU)). In addition, these samples were resubmitted for analysis with different sample numbers. Tables A-1 and A-2 illustrate this data. These data are presented as a function of spill-site number, date that the sample was collected, contractor performing the analysis, and individual and average values for the data. When two contractors are given for a single sampling date, this indicates that identical samples were submitted to the contractors for analysis. Values appearing for 2,4-D, 2,4,5-T, or dioxin and performed by a single contractor for a single sampling date, indicate that identical samples were submitted to the contractors under different sample numbers. The very wide fluctuations in 2,4-D, 2,4,5-T, and dioxin between analyses for identical samples by a laboratory and between laboratories are noted by examining the sample deviations listed under laboratory average and date average, respectively, in Tables A-1 and A-2. Again, in most cases, the individual values are within a factor of 2 of the mean value. This very large variability in the data, the very slow rate of natural degradation of dioxin, and the limited quantity of data available make it impossible to determine a meaningful half-life for natural degradation of dioxin.

*Study was performed to evaluate the performance of laboratories prior to contract award.

TABLE A-1. QUALITY CONTROL SUMMARY OF REPRESENTATIVE DATA ON HERBICIDE ORANGE CONTAMINATION AT JOHNSTON ISLAND

SPILL SITE	DATE	CONTRACTOR	2,4-D(ppm)	2,4-D(ppm) LAB AVERAGE	2,4,5-T(ppm)	2,4,5-T(ppm) LAB AVERAGE	TCDD(ppb)	TCDD (ppb) LAB AVERAGE	TCDD (ppb) DATE AVERAGE
TH-10	Jun 81	WSU					148;99	124±35	108±62
		CAL	1700;1100	1400±424	1500;710	1105±599	23,160	92±97	
	Nov 81	WSU					78	78	144±93
		CAL	1500	1500	1200	1200	210	210	
	May 82	WSU					157	157	119±54
		CAL	700	700	920	920	80	80	
TH-12	Jun 81	WSU					33;47	40±10	52±16
		CAL	970;710	840±184	1200;930	1065±191	55;72	64±12	
	Nov 81	WSU					25	25	39±20
		CAL	320	320	570	570	53	53	
	May 82	WSU					85	85	75±14
		CAL	35	35	220	220	65	65	
41	Jun 81	WSU					96.75	86±15	78±34
		CAL	2100;1800	1950±212	2000;1500	1750±354	31;110	71±56	
	Nov 81	WSU					60	60	71±15
		CAL	1200	1200	1500	1500	81	81	
	May 82	WSU					79	79	76±4
		CAL	390	390	1100	1100	73	73	

TABLE A-2. QUALITY CONTROL SUMMARY OF REPRESENTATIVE DATA ON HERBICIDE ORANGE CONTAMINATION AT THE NAVAL CONSTRUCTION BATTALION CENTER

SPILL SITE	DATE	CONTRACTOR	2,4-D(ppm)	2,4-D(ppm) LAB AVERAGE	2,4,5-T(ppm)	2,4,5-T(ppm) LAB AVERAGE	TCDD(ppb)	TCDD (ppb) LAB AVERAGE	TCDD (ppb) DATE AVERAGE
1	May 81	WSU					123;134	129±8	154±31
		CAL	290;760	525±332	200;1100	650±636	190;170	180±14	
	Nov 81	WSU					154	154	197±61
		CAL	130	130	200	200	240	240	
	Apr 82	WSU					130	130	153±33
		CAL	22	22	74	74	176	176	
17	May 81	WSU					160;227	194±47	171±56
		CAL	5600;4400	5000±849	3200;4200	3700±707	97;200	149±73	
	Nov 81	WSU					168	168	214±65
		CAL	1200	1200	1700	1700	260	260	
	Apr 82	WSU					337	337	304±47
		CAL	796	796	2770	2770	271	271	
41	May 81	WSU					80;180	130±71	120±62
		CAL	3400;2700	3050±495	2100;1600	1850±354	54;165	110±78	
	Nov 81	WSU					123	123	132±12
		CAL	600	600	1100	1100	140	140	
	Apr 82	WSU					249	249	200±70
		CAL	110	110	570	570	150	150	

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